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# Measurements of thermal properties of rocks and minerals at formation conditions: equipment and results

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An instrument for measurements of rock's and mineral's thermal conductivity (TC) and thermal diffusivity (TD) with simultaneous influence of temperature (up to 250 $^{o}$C), pore and two components of lithostatic pressures (up to 200 MPa) has been developed. A new approach in line-source method has been found to provide simultaneous measurements of TC and TD tensor components within one PT cycle.

According to metrological testing performed on set of 6 reference samples with TC and TD values within ranges of respectively 0.71...10.7 W/(m·K) and (0.557...5.42) $\cdot 10^{-6}$ m$^2$/s and testing on quartz single crystal at simultaneous influence of elevated temperature and pressure, accuracy+precision of TC and TD has been established to be correspondingly 4 and 7%.

A special approach has been elaborated to provide a control of changes in inner pore structure and matrix thermal properties during PT measurements. The approach includes (1) measurements of TC and TD of samples studied at normal conditions using the high-precision optical scanning instrument; (2) estimation of inner pore space structure and matrix thermal properties from TC measurements on dry and fluid-saturated rock samples with theoretical models based on effective medium theory.

Behavior of TC and TD tensor components of quartz, calcite and potassium feldspar single crystals have been registered at simultaneous influence of temperature (up to 220 $^{o}$C) and confining pressure (up to 200 MPa). Analysis of experimental data and

comparison with literature data have revealed that average difference in their values (1) does not exceed 5% for quartz, and (2) increases systematically up to 12% with P&T increase for calcite single crystal.

Totally 102 sedimentary and crystalline samples (with porosity ranged respectively 0.2...36 and 0.1...3%) from Chesapeake impact structure (USA), Ural superdeep well SG-4 (Russia) and territory of Germany have been studied at simultaneous influence of temperature and pressure. During studying of porous sedimentary rock samples pore pressure was set to be equal to 1/2.5 of overburden pressure.

According to the results of thermal property measurements on *sedimentary rocks* at elevated temperature (25...220) $^{o}$C and equal vertical and horizontal components of lithostatic pressure (up to 200 MPa) and pore pressure (up to 80 MPa) TC and TD have varied at pressure of 180 MPa and temperature of 120 $^{o}$C by -9.2...-46% and -64...-14% respectively. Correlation between slope angle of TC(P,T) curves and TC values at normal PT conditions has been found to be close for sandstones and carbonate rocks with correlation coefficients -0.81 and -0.91, correspondingly.

Results of TC/TD measurements on *crystalline rocks* at elevated temperature (25...120) $^{o}$C and equal vertical and horizontal components of lithostatic pressure have shown that thermal conductivity and thermal diffusivity vary at pressure of 170 MPa and temperature of 120 $^{o}$C by -5.9...-26 % and -11.2...-33% respectively. For the Ural superdeep well SG-4 TC values decrease up to 11% at PT conditions corresponding to the sampling depths (up to 6 km) in comparison to TC values at normal conditions that was accounted for heat flow density estimation.

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